論文 / 著書情報
Article / Book Information

題目(和文)	生体分子から着想を得た交互両親媒性分子の物性と機能評価
Title(English)	Study on Properties and Functions of Bioinspired Multiblock Amphiphiles
著者(和文)	森水紀
Author(English)	Miki Mori
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12430号, 授与年月日:2023年3月26日, 学位の種別:課程博士, 審査員:金原 数,丸山 厚,上野 隆史,秦 猛志,堤 浩
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12430号, Conferred date:2023/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Study on Properties and Functions of Bioinspired Multiblock Amphiphiles
（生体分子から着想を得た交互両親媒性分子の物性と機能評価）

Miki MORI
Academic supervisor: Prof. Kazushi KINBARA

Biological organisms maintain their homeostasis via complex interaction and communication between biomolecules. The functions of biomolecules are rich in variety and their structures are precisely controlled for their functions. Therefore, biomolecules are attractive structural motif to construct complex, functional molecular systems from bottom-up approaches. Learning from nature, chemists have been developing artificial protocell models that can perform life-like functions such as communication, compartmentalization, replication, and metabolism. Such molecular systems are expected to bridge the gap between living organisms and non-living chemical species and give us clues on how life emerged on the early Earth. In the thesis, the author especially focused on developing synthetic molecules that can function in/as artificial cell compartments.

In chapter 1, the author gave brief introduction on compartmentalization in the cells, which play crucial roles in bringing order to complex network of biomolecules. Then, the author overviewed the strategies to build and functionalize artificial cell compartments that mimic the biological systems by giving examples of recent studies.

In chapter 2, the function of newly developed imidazolinium-based multiblock amphiphile (**IMA**) was investigated using liposomes as cell models. **IMA** consists of hydrophilic oligo(ethylene glycol) chains and hydrophobic aromatic unit with imidazolinium at its center (**Figure**). Here, the author focused on investigation of the transmembrane ion transport activity since imidazolinium derivatives are known to recognize anions via C–H$^{+}\cdots$X^{-} hydrogen bonds. Ion transport assay using small unilamellar vesicles (SUVs) encapsulating pH-sensitive 8-hydroxypyrene-1,3,6-trisulfonic acid (HPTS) and chloride-sensitive lucigenin dyes revealed that **IMA** transports anions across the membranes and showed selectivity for nitrate. The ion transport mechanism was further investigated by controlling the fluidity of the membranes in the HPTS assay, which indicated that **IMA** transport ions as a mobile carrier. Spectroscopic analysis using SUVs containing spin-labeled lipids revealed that **IMA** prefers to localize near the membrane surface close to the aqueous layer rather than the center of the hydrophobic layer, further supporting the carrier mechanism in ion transport. Hill analysis was carried out to evaluate the stoichiometry of **IMA** and chloride ion during ion transportation, which indicated the formation of a dimeric complex. The interaction between chloride ion and **IMA** was examined by ^{1}H NMR titration experiment, which showed the presence of C–H$^{+}\cdots$X^{-} hydrogen bond of the imidazolinium moiety. These experimental results were in good agreement with the all-atom molecular dynamic simulations.

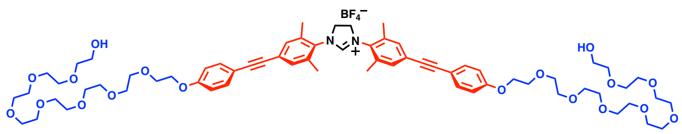

Figure. Molecular structure of **IMA**. Red, blue and black represent the hydrophobic, hydrophilic, and imidazolinium unit, respectively.

In chapter 3, further investigation on the properties of **IMA** was carried out in solutions and in lipid bilayer membranes. From the spectroscopic studies using various solvents, the author found that **IMA** could take diverse self-assembling states depending on the solvents. **IMA** dissolved in THF (**IMA**$_T$) and $CHCl_3$ (**IMA**$_C$) showed characteristic emission band around 300 nm and 465 nm upon excitation at 295 and 320 nm, respectively. Hence, transmission electron microscopic observation was carried out for these two solutions and two types of self-assembling states were observed: **IMA**$_T$ gave sharp-edged ribbon-like structure, whereas **IMA**$_C$ gave spherical aggregates. Microscopic observation using giant unilamellar vesicles revealed that **IMA**$_T$ and **IMA**$_C$ could both be incorporated into the lipid bilayer membranes. Further spectroscopic analysis using SUVs revealed that emission property of **IMA**$_T$ and **IMA**$_C$ was maintained within the lipid bilayer membranes. These results suggest that **IMA**$_T$ and **IMA**$_C$ could be transferred to the lipid bilayer membranes. The author successfully controlled the self-assembling state of **IMA** by properly choosing the solvent used for membrane incorporation.

In chapter 4, the author newly synthesized multiblock amphiphilic Hoveyda-Grubbs catalyst (**MAHGII**) and investigated its properties in aqueous environment. **MAHGII** showed unique characteristics that can be seen for liquid droplets. **MAHGII** droplets could fuse with each other and accumulate the hydrophobic molecules. Furthermore, **MAHGII** was capable of catalyzing olefin metathesis reaction not only in organic solvent but also in aqueous media.

In chapter 5, conclusion of the thesis and perspectives are mentioned.

Throughout the thesis, the author investigated the properties and functions of newly developed multiblock amphiphiles **IMA** and **MAHGII**. These molecules exhibited unique functions in/as artificial cell compartments. The author expects that these results would contribute to further development of protocell models with life-like functions which ultimately lead to construction of artificial cells from bottom-up approaches.